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Effect of Hot Water Treatment of In-Shell Pecans on Physico-Chemical Properties and Consumer Acceptability of Roasted Pecan Kernels

Running title: Quality of Hot Water Treated Pecans

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Summary

The effect of hot water pre-treatment of in-shell pecans on physicochemical properties, consumer acceptance and purchase intent of dehulled and roasted kernels was evaluated. In-shell pecans were first subjected to hot water at 70, 80 and 90ºC for 8.6, 6.6 and 4.6 min, respectively and kernels were later dry roasted at 160^{0}C for 10 min. The physicochemical properties of hot water treated and untreated nuts, before and after roasting were determined. Furthermore, consumer acceptance and purchase intent of the roasted kernels were determined. Hot water treatment, alone, and subsequent roasting had minimal effect on pecans' physicochemical properties. Consumers liked (P<0.05) colour and aroma of treated pecans. No effect (P>0.05) of pre-treatment was observed on acceptability of other sensory attributes. Safety claim increased treated pecans' overall liking; however, it decreased purchase intent. Hot water treatment showed promise as a post-harvest microbial intervention strategy without affecting the physicochemical properties and consumer acceptability.

Introduction

Pecans are commercially important nut crop in the U.S.A and are one of the most favoured tree nuts, worldwide. Usually, pecans were sold as whole, pieces, meal or most often used as an ingredient in desserts, ice-cream or candies (Lombardini *et al*., 2008). Pecans are a rich source of nutrients and several antioxidants due to the presence of phenolic compounds, condensed tannins and hydrolysable tannins (Flores-Cordova *et al*., 2017). These properties are effective against various diseases (Beuchat & Pegg, 2013; Santerre, 1994b) and help lower the frequency of several chronic diseases like cancer, Alzheimer's disease, Parkinson's disease and other degenerative diseases (Mertens-Talcott & Percival, 2005; Tam *et al*., 2006). Also, the high amount of monounsaturated fatty acid in pecans plays an important role in lowering the LDL cholesterol and minimising the risk of heart disease (Rajaram *et al.*, 2001).

On the other hand, pecans can be susceptible to pre and post-harvest microbial contamination (Beuchat & Pegg, 2013) that can lead to food-borne illnesses. During pre and post-harvest operations, pecans may come in contact with orchard floors, soil, water, food contact surfaces among others potentially exposing the nut surfaces to microbial contamination (Isaacs *et al*., 2005). In the past few years various tree nuts including pecans, mixed nuts as well as peanuts have repeatedly been associated with recalls and outbreaks due to contamination with food-borne pathogens such as *Salmonella*, *Escherichia coli* O157:H7 and *Listeria monocytogenes* (Zhang *et al*., 2017). Post-harvest treatment of in-shell pecans should include a step to mitigate the risk associated with pre-harvest microbial contamination. Hot water conditioning is one of the post-harvest processing steps of pecans that aid in kernel separation, minimise kernel breakage and increase the shelling efficiency as well as aid in decontamination of pecans (Beuchat & Pegg, 2013). Studies indicated that pre-treatment of pecan with hot water may significantly reduce the microbial food safety risks associated with *Salmonella enterica* (Beuchat & Mann, 2011a). Our previous study showed that the hot water treatment of in-shell pecans at 70°C for 8.6 min, or 80°C for 6.0 min, or 90°C for 4.6 min can be used successfully to achieve a minimum of 5-log reduction of various bacterial pathogens of public health concern such as *Salmonella enterica, E. coli* O157:H7 and *Listeria monocytogenes* (Kharel *et al.*, 2018).

Nevertheless, heat treatment can also affect the quality of treated food. Blanching and roasting can bring significant changes in colour, flavour and texture of nuts where, blanching can lead to softening of nut texture while roasting can change the flavour and skin colour (Prakash, 2013). A study by Forbus and Senter (1976) found that when in-shell pecans were steam treated at 100°C for 3 min the kernels appeared darker in colour and gained slightly cooked flavour. To our knowledge, the quality and consumer acceptability of pecan kernels from the hot water treated in-shell pecans have not been demonstrated; which is very critical for practical implementation. Thus, the main objectives of this study were to: i) determine the effect of hot water pre-treatment (Kharel *et al.*, 2018) and roasting on the physico-chemical properties of pecan kernels ii) evaluate consumer acceptability and purchase intent of hot water pre-treated and roasted pecans.

Materials and methods

Selection of pecans

Raw in-shell pecans (*Carya illinoinensis)* of Sumner variety harvested during September-October season of 2016-2017 were obtained from Little Eva Pecan Company LLC, Cloutierville, Louisiana, USA. The pecans were contained in a polypropylene mesh bags and stored at 4°C, to maintain the quality, for approximately a month, until further use.

Hot water treatment of pecans

A 2 kg of undamaged in-shell pecans were weighed using a calibrated balance (PG 5001-S, Mettler Toledo, Columbus, OH). A skillet (SGL40TR, Cleveland Range, Cleveland, Ohio, USA) with dimensions 85 x 65 x 23 cm^3 (l x b x h) containing water at a depth of 10 cm was heated up to either 70, 80, or 90±2ºC. The in-shell pecans were placed in stainless steel strainers (34 x 23 x 10.5 cm^3) and then dipped in the hot water maintained at 70, 80, and 90°C for 8.6, 6.6 and 4.6 min, respectively. The temperature of skillet surface, hot water and the surface of the nuts were continuously measured using a data logger (SDL200, ExTech, Nashua, NH) attached with K-type thermocouples. The time-temperature combinations were selected based on calculated D-values to achieve 5-log reductions of bacterial pathogens (Kharel *et al*., 2018).

Roasting of pecans

The hot water treated in-shell pecans were placed on metal trays (65 x 45 cm^2) and air dried to room temperature (21°C) for 1 h. After that, the pecans were de-shelled using nut crackers without damaging the kernels and dry roasted. A mini rotating rack convection oven (OV310E, Baxter Model, Orting, WA, USA) was preheated to 160±3°C and the trays containing shelled pecans were put in the oven for 10 min at 160°C. This roasting condition mimics the dry roasting conditions at pecan industry and was selected based on one of the treatment combinations used in the study for hot air roasting of pecans (Beuchat & Mann, 2011b). The pecan kernels treated with hot water at 70, 80 and 90°C were labelled as T1, T2, and T3, respectively; and, the subsequently roasted pecan kernels were labelled as RT1, RT2 and RT3. Total two different control groups viz., raw pecans (C1) and raw pecans directly roasted (RC1) were also included for comparison. The treated and control pecan kernels were vacuum packed in metallised poly food bags (S-6177, Uline, Atlanta, Georgia, USA) using a vacuum sealer (UV550, Koch, MO, USA). The bags were then stored at 4°C for approximately 3 days before further analysis.

Analysis of physico-chemical properties

Physico-chemical properties of all the pecan samples, i.e. raw (C1), hot water treated (T1, T2, T3) and subsequently roasted (RC1, RT1, RT2, RT3) pecan kernels were measured. Pecans (25 g) were ground using a magic bullet blender (Magic bullet, Los Angeles, CA, USA) for the analysis of moisture and water activity. Moisture content was measured in triplicate by thermo gravimetric method using a moisture analyser (MJ33, Mettler Toledo, Switzerland) and the water activity was measured in triplicate at 25°C using Novasina Labtouch water activity meter (Neutec Group Inc, NY, USA).

For colour measurement, 3 pecan halves were placed on the top port of the spectrophotometer (CM-5 Konica Minolta, Inc., NJ, USA) and the L* (0=black and 100=white), a*(+a*= redness, -a*=greenness), b*(+b* =yellow, -b* =blue) were measured. Readings were taken in triplicates for each sample where samples were rotated at ~90° on the top port after each reading. The chroma $(a^{*2}+b^{*2})^{1/2}$ and hue angles ($\tan^{-1}$ (b*/a*) were calculated. To evaluate the overall colour difference between a sample and the reference, total colour difference (ΔE) was calculated using the following equation (Caivano, 2012),

$$\Delta E^{*} = \sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})}$$

Where, $\Delta L^{*} = (L_1^{*}-L_0^{*})$; $\Delta a^{*}=(a_1^{*}-a_0^{*})$; and $\Delta b^{*}=(b_1^{*}-b_0^{*})$

Total colour difference has been used as a tool to assess colour difference between test and the reference sample. The following scale was used to evaluate the colour difference: ΔE^{*}=0-0.5, trace level difference; ΔE^{*}=0.5-1.5, slight difference; ΔE^{*}=1.5-3.0, noticeable difference; ΔE^{*}=3.0-6.0, appreciable difference; ΔE^{*}=6.0-12.0, large difference; and ΔE^{*}>12.0, very obvious difference (Chen & Mujundar, 2008).

The texture of pecan samples was analysed using a texture analyser (TA-XT plus Texture Analyzer, Texture Technologies Corp, NY, USA) with a sharp blade probe (HDP/BS) following the protocol by Lee and Resurreccion (2006) for roasted peanuts. The blade was lowered with cross head speed of 250 mm/min and 20 mm distance from the platform to cut across the kernel line. The peak force (N) required to break the pecan kernel before the cross head moved away from the platform was recorded as Hardness. The mean value of twenty measurements was reported as hardness (N).

Microbiological analysis

Prior to consumer study, aerobic plate count and yeast and mould count on the roasted pecan kernels (RC1 and RT1, RT2 and RT3) were determined in duplicates using 3M^{TM} Petrifilms^{TM} (3M^{TM} Petrifilms^{TM}, St. Paul, MN) by following manufacturer's instructions. Experiment was performed in duplicates. No growth was observed in the samples.

Consumer liking and purchase intent

The sensory study was approved by the LSU Institutional Review Board with the IRB exempt number of HE 15-9. Consumer test was conducted with 112 panellists (47.3% male and 52.7% female) who were faculty, staff and students at Louisiana State University, Baton Rouge, LA, USA. Sensory booths illuminated with cool, natural, fluorescent lights were used for sensory evaluation and questionnaires were developed through Compusense® five (Compusense Inc., Guelph, Canada) software. Consumers read and electronically signed a consent form [screening criteria including not allergic to pecans and unsalted crackers]. Samples, coded with 3-digit random number, were presented using a randomised complete block design in which each consumer was presented with four pecan samples in 2 oz serving size cups in a counterbalanced protocol so as to minimise psychological biasness on the order of sample presentation. The four pecan samples presented were roasted raw pecans (control RC1) and roasted pecans pre-treated with hot water at three respective time-temperature combination, i.e., RT1, RT2 and RT3.

Consumers were instructed to evaluate the acceptability of 5 attributes namely, appearance /colour, aroma, texture (crunchiness), flavour and overall liking using a 9-point hedonic scale (1-dislike extremely, 5=neither like nor dislike, 9=like extremely). Immediately following the acceptability test, a purchase intent question was asked using a binomial (yes/no) scale.

Consumers were then informed for each sample whether it had been processed with hot water prior to roasting for safety of pecans. The claim displayed for hot water treated sample was

"The *shells of these pecans were treated with hot water making them safer for consumption*" whereas, for the control sample was "*The shells of these pecans were not treated with hot water*". Consequently, they were again asked to evaluate each sample on their overall liking and purchase intent. Unsalted plain crackers and water were provided to cleanse the palate between samples.

Statistical analysis

The mean differences of physicochemical properties and consumer liking were evaluated using analysis of variance (ANOVA) followed by Tukey's adjustment test for *post hoc* multiple comparisons. Significant differences in the purchase intent (%) under different treatments was analysed using Cochran's Q test. McNemar's test was carried out to analyse significant difference in the percentage change in purchase intent before/after the safety claim. All the values were considered significantly different at $P<0.05$. (SAS software Version 9.1, SAS institute Inc., Cary, NC, USA).

Results and discussion

Moisture and water activity

The hot water treatment alone at different temperatures did not show significant effect ($P>0.05$) on the moisture content of the pecan kernels (Table. 1). The moisture content of raw pecan kernels after hot water pre-treatment ranged from 6.09 to 6.97 % (Table. 1). However, the difference was not statistically significant ($P>0.05$). Roasting process showed significant effect on the moisture content of the kernels when compared to unroasted kernels. However, the mean moisture values (2.06-2.94%) after roasting were not significantly ($P>0.05$) different among the treatments. Similarly, the water activity of the raw pecan kernels (C1, 0.81) increased after hot water pre-treatment up to 0.85 (with 90°C treatment) but reduced to 0.35 (control RC1) and 0.44 (with 70, 80, and 90°C treatment) upon dry roasting (Table. 1). A study by Beuchat and Mann (2010) showed that the rate of infiltration of water into in-shell pecans depends on the temperature of water to which the in-shell pecans are exposed. When the pecans were exposed to hot water (66 to 93°C), the water activity of pecan kernels increased with increasing temperature of the water as it infiltrated through the shell (Beuchat & Mann, 2010). The observed findings corroborate with the results from the present study where higher water activity values were observed for pecans hot water treated at higher temperature, irrespective of the exposure time.

Moisture content and water activity are important parameters that affect the shelf-life of nuts. A good quality pecan kernel of 4.3-4.5% moisture is shown to have water activity in the range of 0.65-0.70 (Santerre, 1994a). In this study, we observed slight increase in moisture content of pecan kernels after hot water treatment. Normally, conditioning increases the moisture of pecan nutmeats from 4 to 8% which makes it more flexible and reduces kernel breakage while cracking the nut (Santerre, 1994b). After that, the pecan kernels will be dried to 3-4% moisture content to reduce mould growth, rancidity and maintain quality that is desired by consumers (Santerre, 1994b). Pecans have approximately 65-75% of lipid content (Santerre, 1994b) thus the hot water treatment could have an impact on its lipid stability. However, the present research work did not focus on the shelf-life and oil quality of pecan kernels. Thus, effect of hot water treatment on the lipid stability of pecan kernels can be investigated in future research works.

Moisture content of raw pecans observed in our study was higher than that of raw pecans (3.5-3.76%) reported by Resurreccion and Heaton (1987). Varietal difference, time of harvest of pecans and type of post-harvest drying process can result in such discrepancies. A study by Beuchat and Mann (2011b) showed that moisture content and water activity of pecans after hot air roasting was dependent on its initial moisture, a_w values and roasting conditions. When pecans containing 2.8-4.1% moisture (0.52-0.61 a_w) were hot air roasted at 120°C for 10 min, values decreased to 1-2% moisture (0.1-0.25 a_w) whereas, pecans at 10.5-11.2% moisture (0.94-0.96 a_w) reached to 2.2-3% moisture (0.4-0.45 a_w) (Beuchat & Mann, 2011). Our results were similar to the observed findings indicating minimal effect of hot water conditioning at the tested conditions on the moisture content and water activity of pecan kernels.

Texture

Hardness is measured by the peak force (N) required during the compression of any material and it has been used as an indicator of textural quality during roasting of various low water activity foods like sesame seeds (Kahyaoglu & Kaya, 2006), peanuts and pistachio (Nikzadeh & Sedaghat, 2008; Raei *et al.*, 2009). In our study, raw pecans (C1) showed highest hardness value (45.7±13.60 N) followed by the pecans that were hot water treated at 90 (43.05±9.42 N), 80

(40.86±6.21 N) and 70°C (40.75±9.83 N), respectively (Table. 1). However, the difference was not significant (P>0.05) indicating minimal effect of hot water treatment on textural property of pecan kernels. Upon roasting, the hardness value of raw pecans (RC1) significantly (P<0.05) decreased to 35.66±7.16 N. While the hot water pre-treated pecans tend to exhibit lower hardness values after roasting; the difference was not significant. Overall, after roasting the hardness value of pecans (control or hot water pre-treated) were similar (P>0.05) (Fig. 1S (b)).

A study by Moghaddam *et al.* (2016) indicated that higher roasting temperature will result in decreased hardness value. At roasting temperature of 90°C the hardness value of pistachio kernel was 82.76 N, however, when the roasting temperature was increased to 150°C the hardness value decreased to 37.59 N. This is similar to the hardness value we observed for our pecan kernels while roasting at temperature 160^{o}C. Roasting conditions are shown to affect the textural property of nuts as it decreases its moisture content (Boge *et al.*, 2009), resulting in fragile and crumbly texture (Vincent, 2004). In our study, hot water treatment did not have pronounced effect on the hardness of pecans; however, after roasting, pecans, particularly hot water treated at 90ºC, tentatively required less force to get deformed which can be owing to its brittle nature due to removal of moisture (Table. 1).

Colour

The effect of hot water treatment and roasting on colour of pecans is presented in Table. 1. As the pecans were treated with hot water, L* values tentatively decreased from 47.09±0.28 (control, C1) to 45.74-47.05 but with no significant (P>0.05) difference. Lower L* indicates darker colour. This shows that there was minimum effect of hot water treatment on the colour of pecan kernels. However, when the pecan kernels were roasted, the L* values of pecans pre-treated with hot water at 70, 80 and 90°C further decreased to 44.76±0.07, 44.69±1.08 and 41.87±0.69, respectively, which was significantly (P<0.05) lower than that of control (RC1) (47.18±0.30). This indicated that hot water pre-treated pecans became darker on roasting. The L* value was also seen to be inversely related to the hot water treatment temperature when the nuts were roasted. Among all the samples, roasted control pecans (RC1) was the lightest (L* = 47.18±0.30) while roasted pecan that was pre-treated with hot water at 90° (RT3) was the darkest (L*= 41.87±0.69) (Fig. 1S (c)).

The lowering of L* value of pecans after roasting is because of the browning and caramelisation reactions which are responsible for brown colour formation. Browning reaction, i.e., a non-enzymatic reaction occurs when a reducing sugar and protein are heated together (McDaniel *et al*., 2012). A study on roasting of hazel nuts showed that non-enzymatic browning played an important role in the development of colour and flavour of the roasted nut (Saklar *et al.*, 2001). Also, the darker brown colour of hot water pre-treated pecans can be attributed to its higher water activity values than that of roasted control (Fig. 1S (a).). High water activity in food means that there is increased mobility of reactants as a result, the reaction rate of non-enzymatic browning reaction increases (Hedegaard and Skibsted, 2013). The results were also supported by the total colour difference values (ΔE). It indicates that pecans subjected to hot water treatment showed noticeable difference in the colour in comparison to control (C1). As the pecans were roasted, there was appreciable to large colour change (Chen & Mujundar, 2008) in pecans that were hot water pre-treated.

A colour wheel was used to measure the hue angles of pecans in which 0° means +a* (red) and 90° means +b* (yellow). The hot water treatment tentatively increased the hue angles of pecans from 63.16° (C1) to 63.34-64.26° while roasting tentatively decreased the value to 62.25 (RC1) for control and to 59.88-62.19° for hot water pre-treated pecans; however, the change was not significant ($P>0.05$). This indicates minimal effect of hot water treatment and/or roasting on the hue value of pecans. The hue value indicated that colour of the pecan kernels was towards the yellowish shade. Furthermore, chroma values ranged from 23.69-30.69; with an increase in temperature of hot water treatment the chroma values (saturation) of the pecan nutmeat were found to increase but it decreased on roasting. Chroma value starts at the 0 in the centre of the colour wheel and is a distance from the lightness axis. Observed chroma value in the study indicates that the pecans had darker yellow shade. Colour of the food is linked with its quality attributes like freshness, sensory, nutritional and defects (visual and non-visual). Unwanted changes in colour can lead to decreased consumer's acceptance and its worth in the market thus is one of the important appearance attributes (Xiao *et al.*, 2017). A study on traditionally harvested pecans found the colour values of the nut to be 31.58-35.67 (L*), 10.06-10.77 (a*), 13.61-15.92 (b*) and a hue angle of 51.63-52.72° (Resurreccion & Heaton, 1987). These values were similar but slightly lower than values observed in our study which can be attributed to varietal difference of pecans and post-harvest processing of nuts. Thus, colour of the shelled pecan (dark yellow) was maintained even after hot water treatment and roasting process. However, hot water treatment made the kernels look darker on roasting as seen from their lower L* values as compared to roasted control pecan (RC1).

Consumer liking

The effect of hot water pre-treatment on the liking scores for various sensory attributes of roasted pecans is presented in Table. 2. Among the tested sensory attributes, hot water pre-treatment showed a significant effect on the liking of colour and aroma of the roasted pecans. The mean liking scores for colour of the roasted pecans significantly (P<0.05) increased from 5.2 (roasted control, RC1) to 6.79 (90°C treatment, RT3) whereas mean values for aroma increased (P<0.05) from 5.79 (roasted control, RC1) to 6.42 (90°C treatment, RT3). The liking score was found to increase with increasing temperature of hot water pre-treatment but was not significant. As seen from L* value in Fig. 1S (c), roasted pecans became darker as the hot water temperature was increased. This indicated that consumers liked the darker colour the pecans gained due to hot water treatment.

Consumers slightly-moderately liked the texture of roasted pecans as the liking scores for texture ranged from 6.49-6.64. However, there were no significant differences between the control (RC1) and hot water pre-treated pecans (RT1, RT2 and RT3). This result was analogous to our findings in Table. 1 which showed that the hardness values of roasted pecans (control, RC1 or hot water pre-treated) were not significantly different when measured by the texture analyser. As for the flavour, liking scores for the roasted pecans (control, RC1 and hot water pre-treated) ranged from 6.17-6.42 with no significant difference among the mean values. This demonstrated that hot water pre-treatment had no significant effect on the texture and flavour liking of roasted pecans whereas; the treatment significantly enhanced its colour and aroma liking. A study by Beuchat and Heaton (1975) showed a slow increase in internal nut temperature when in-shell pecans were submerged in hot water. The poor heat conductivity of the porous packing tissue alongside the high amount of fat content in the nutmeat was believed to slow down the heat transfer within pecan shells (Beuchat & Heaton, 1975). Thus, minimum heat penetration from the shell to pecan kernel could be one of the reasons for minimal effect of hot water treatment on the kernel properties. Hot water pre-treatment did not show a significant (P>0.05) effect on the overall liking of roasted pecans. The overall liking scores ranged from

6.29-6.46 before any safety claim was shown. In the later part of the study, consumers were informed that pecans were hot water pre-treated that made the pecans safer to consume. After the safety claim was displayed, the overall liking of the pecans slightly increased from 6.42 to 6.53, 6.29 to 6.43 and 6.46 to 6.52 for 70, 80 and 90°C hot water pre-treated pecans, respectively, while there was a slight drop in the overall liking from 6.31 to 6.21 for the control (RC1) pecans. Studies have shown that overall liking increased for products after the health benefit statement or safety disclaimer was shown. For example, a consumer liking and purchase intent study on sponge cakes showed that overall liking of the product increased after the health benefit statement was displayed and it was one of the important attributes that influenced purchase intent (Poonnakasem *et al.*, 2016). Likewise, another study on pomegranate juice and green tea blends found that claim about health benefits had a positive impact on overall liking of the product (Higa *et al.*, 2017). These findings were parallel with our result which showed a positive effect of safety claim on the overall liking of hot water pre-treated pecans.

Purchase intent

Purchase intent has been reported to be positively influenced by additional product information and health benefit statement (Lee *et al.*, 2015; Poti *et al.*, 2015; Sukkwai *et al.*, 2017)**.** In this study, the safety claim showed an increase in overall liking of hot water pre-treated pecans; however, a drop in purchase intent was observed after the claim. The highest purchase intent, before the claim, was observed for the roasted pecans that were hot water pre-treated at 90°C which could likely be due to consumers' liking for its appearance/colour, aroma and overall liking (Table. 2). Still, there was a significant decrease in purchase intent from 39.29 to 33.04% after the claim was shown. On the other hand, consumers intended to purchase the control pecans more, after the claim was displayed. The purchase intent for the control pecans (RC1) significantly increased from 37.5% to 43.75%, despite the lower overall liking scores after the claim. This showed that claim about hot water treatment for safety of pecans may have a negative impact on its purchase intent even though the consumers liked the treated pecans. A study on impact of claims on consumer perception about pre-biotic enriched breads found that even though there was no change in overall liking of the product when the claim was presented, there was decrease in the purchase intent by one of the clusters of people who were not receptive towards the claims. Consumers found them hard to understand and were sceptical on the truth of the claims (Coleman *et al.*, 2014). This could be one of the probable reasons for the decrease in purchase intent in our study. Lack of information on the process and technology used to make the product has also been reported to be one of the probable causes for the decreased purchase intent. A study by Lee *et al.* (2015) showed that consumers were cynical about the non-thermal technology used until they had detailed information about it. After being informed, participants' perception towards the technology changed which resulted in an increased purchase intent of the treated product (Lee *et al.*, 2015).

Additionally, there is also an increased consumer demand for minimally processed foods, clean label foods and the trend of healthy eating has gained attention in consumers. Plain nuts are categorized as unprocessed or minimally processed foods (Poti *et al.*, 2015). Although hot water treatment step is one of the conventional pecan processing steps, the hot water treatment step used in this study could have been regarded as an added heat treatment step by consumers which may be the reason for decreased purchase intent of the hot water treated pecans.

Conclusion

This study demonstrated the effect of hot water treatment of in-shell pecans on the physico-chemical properties and consumer acceptability of roasted pecan kernels. Under the tested conditions, there was no drastic effect of hot water treatment of in-shell pecans on moisture content, water activity and texture of pecan kernels. From the instrumental analysis, it was observed that roasting the hot water pre-treated pecans made the kernels appear darker. As the temperature of hot water pre-treatment increased the roasted kernels became darker. This attribute was liked by consumers as they gave higher liking scores for the colour and aroma of roasted pecans pre-treated with hot water. Consumers did not find any significant effect of hot water pre-treatment on the texture, flavour and overall liking of the roasted pecans. However, the overall liking and purchase intent were affected by the safety claim. The overall liking increased after the safety claim was displayed but a negative effect was seen on the purchase intent of the pecans. Thus, conditioning the in-shell pecans with hot water was found to show a positive effect on pecan kernels' quality and acceptability. Educating consumers about the hot water treatment and its effect on safety of pecans would certainly increase purchase intent and needs further studies to confirm such hypothesis.

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Legends to Figures

Figure 1S. The effect of roasting on a) water activity b) Hardness (N) and c) Color (L*) of hot water pre-treated pecan kernels. The sample labels are as follows: RC1 – roasted raw pecans, RT1- roasted pecans pre-treated with hot water at 70°C, RT2- roasted pecans pre-treated with hot water at 80°C and RT3 - roasted pecans pre-treated with hot water at 90°C

Table. 1. Physicochemical properties of raw, hot water treated and subsequently roasted (160ºC for 10 min) pecans

Parameters	**Control**		**Hot water treated pecans**					
			Before Roasting			**After Roasting**		
	C1	**RC1**	**T1**	**T2**	**T3**	**RT1**	**RT2**	**RT3**
Moisture (%)	6.45±0.65^{a}	2.06±0.24^{b}	6.48±0.22^{a}	6.09±0.40^{a}	6.97±0.83^{a}	2.94±0.34^{b}	2.84±0.09^{b}	2.39±0.1^{b}
a_w	0.81±0.00^{b}	0.35±0.01^{d}	0.82±0.01^{b}	0.83±0.00^{ab}	0.85±0.02^{a}	0.44±0.02^{c}	0.44±0.00^{c}	0.44±0.01^{c}
Hardness (N)	45.7±13.60^{a}	35.66±7.16^{b}	40.75±9.83^{ab}	40.86±6.21^{ab}	43.05±9.42^{ab}	40.15±13.05^{ab}	38.86±5.69^{ab}	36.14±7.82^{b}
Colour								
L*	47.09±0.28^{a}	47.18±0.30^{a}	45.74±0.28^{ab}	45.81±0.30^{ab}	47.05±0.48^{a}	44.76±0.07^{b}	44.69±1.08^{b}	41.87±0.69^{c}
a*	13.06±0.38^{ab}	11.03±0.22^{b}	13.13±0.13^{a}	13.30±0.98^{a}	13.75±0.32^{a}	13.87±0.09^{a}	12.16±1.20^{ab}	13.01±0.33^{ab}
b*	25.83±0.93^{ab}	20.97±0.18^{c}	27.03±0.72^{a}	27.56±0.66^{a}	27.43±1.72^{a}	26.29±0.20^{ab}	23.99±2.53^{abc}	22.61±2.91^{bc}
Chroma	28.95±0.66^{abc}	23.69±0.26^{d}	30.5±0.59^{ab}	30.60±1.02^{ab}	30.69±1.39^{a}	29.72±0.22^{abc}	26.93±2.28^{bcd}	26.12±2.49^{cd}
Hue (°)	63.16±1.51^{a}	62.25±0.26^{a}	64.08±0.82^{a}	64.26±1.11^{a}	63.34±1.97^{a}	62.19±0.03^{a}	63.01±3.42^{a}	59.88±3.31^{a}
ΔE	0^{c}	0^{c}	2.29±0.94^{bc}	2.52±1.26^{bc}	2.04±0.72^{bc}	6.50±0.05^{a}	4.49±1.54^{ab}	6.31±0.92^{a}

Mean ± standard deviation values in the same row with different letters are significantly different ($P<0.05$).

C1 and RC1 represents raw pecans and roasted raw pecans, respectively.

T1, T2 and T3 represents in-shell pecans treated with hot water at 70, 80 and 90ºC, respectively and RT1, RT2 and RT3 are the subsequently roasted kernels from in-shell pecans treated at T1, T2 and T3, respectively.

ΔE for T1, T2 and T3 was calculated using C1 as reference and ΔE for RT1, RT2 and RT3 was calculated using RC1 as reference.

Table. 2. Consumer acceptability scores$^{\beta}$ and purchase intent before and after the safety claim of roasted (160ºC for 10 min) pecans pre-treated with hot water

Hot water pre-treatment	**Appearance/ Colour**	**Aroma**	**Texture**	**Flavour**	**OLb**	**OLa**	**PIb (%)$^{\mu}$**	**PIa (%)$^{\mu}$**
Control (RC1)	5.2±1.73^{b}	5.79±1.77^{b}	6.63±1.52^{a}	6.29±1.8^{a}	6.31±1.75^{a}	6.21±1.8^{a}	**37.50**^{a}	**43.75**^{a}
70°C	6.46±1.45^{a}	6.32±1.47^{a}	6.64±1.57^{a}	6.42±1.7^{a}	6.42±1.58^{a}	6.53±1.5^{a}	33.04^{a}	30.36^{a}
80°C	6.70±1.56^{a}	6.37±1.51^{a}	6.49±1.61^{a}	6.17±1.8^{a}	6.29±1.71^{a}	6.43±1.7^{a}	35.71^{a}	35.71^{a}
90°C	6.79±1.39^{a}	6.42±1.66^{a}	6.58±1.69^{a}	6.21±1.7^{a}	6.46±1.62^{a}	6.52±1.6^{a}	**39.29**^{a}	**33.04**^{a}

β Mean and standard deviation from 112 consumer responses based on 9-point hedonic scale. Mean values in the same column by different letters are significantly different ($P<0.05$).

Control (RC1) is the raw pecans that was subsequently roasted at 160ºC for 10 min.

OLb and Ola refer to Overall liking before and after the safety claim, respectively.

PIb and PIa refer to Purchase intent before and after the safety claim, respectively.

µ Purchase intent (%) in the same column by same letters are not significantly different ($P<0.05$) based on Cochran's Q test

µ Statistically significant values in bold print ($P<0.05$) based on McNemar Exact Probability